# THE SKATE

A LABORATORY MANUAL

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# THE SKATE

*Raja erinacea* Mitchill

*A LABORATORY MANUAL*

BY

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# PREFACE

This manual is written for beginning students and presupposes no previous work in dissection. It is not intended as a treatise on the skate but rather as an introduction to vertebrate anatomy for inexperienced students. It is impossible for the student of comparative anatomy to dissect specimens in as much detail as the student of human anatomy, but he should be so drilled in details as to be capable of working out any vertebrate animal which is employed in further study. It was with such an ideal in mind that this manual was prepared.

Numerous practical reasons may be cited in favor of the dissection of the skate as the introductory study in a course in vertebrate zoology. Students in most beginning courses receive little or no training in the dissection of any vertebrate animal. Experience with many classes in vertebrate zoology at this College and at the University of Kansas has shown that each student needs for his first study an easily dissected **adult** animal. The skate, particularly *Raja erinacea* Mitchill, fits this need in a surprisingly satisfactory way. This skate when fully mature is only sixteen to twenty inches in total length. It is therefore possible to provide the student with a mature specimen of a size convenient for dissection, easy to care for and to work with in the laboratory.

The skate has a very generalized internal structure which is in every way comparable to the shark. It is

superior for laboratory purposes in some ways since the specimens are usually mature, which allows a full dissection of the urogenital system. The body form of the skate is highly specialized, which makes necessary the introduction of demonstration material to illustrate the generalized form. This body shape, however, makes the skate much easier to dissect, since it naturally rests in a suitable position and does not need to be fastened to the dissection board.

The laboratory dissection of the skate conforms with the current textbooks of vertebrate zoology, since it deals with a specimen not discussed or figured in any detail yet serves as an excellent example for comparison with the textbook material on related forms, making possible the legitimate and desirable use of such books in the laboratory.

Besides these fundamental points in its favor the skate is easier to obtain and to store. The cost of skates, according to the prices current with supply companies, is almost one-half that of immature sharks. Only one singly injected specimen is needed for this manual.

Figures of the venous system and the skeleton are included since these systems are most difficult to dissect. The figure of the venous system is unlabeled and is intended to aid in the student's organization of this system. The skeleton of the average specimen is badly injured during dissection but much may be determined with the aid of the figure.

Numerous laboratory guides, outlines and textbooks have been consulted and their suggestions reworked into the present manual during the dissection of many skates in our laboratory. Considerable material has been utilized from "Zootomy" by T. J. Parker, "Outlines of Zoölogy," by J. A. Thompson; "A Laboratory Manual for Compara-

tive Vertebrate Anatomy," by L. H. Hyman, and "Outlines for Comparative Anatomy," by Dr. Peter Okkelberg (unpublished).

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Detroit, Michigan,
January, 1927.

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## A LABORATORY MANUAL

# THE SKATE

(**Raja erinacea** Mitchill)

## CHAPTER I

### GENERAL DIRECTIONS

1. Supplies.

These dissecting instruments and drawing materials are necessary for the course: scalpel, fine scissors, stout and slender probes, forceps with straight points, drawing paper, eraser, hard drawing pencil, ruler, cheese cloth and a towel. A laboratory coat or rubber apron is desirable for the protection of the clothing.

2. Drawings.

Make all drawings on drawing paper with a hard pencil. Draw from the actual material unless the directions state otherwise. Do not make rough sketches to be completed later but do all the drawing work in the laboratory.

Drawings should be large and should show all structures pointed out in the outline. They must be accurate, in correct proportion (use a ruler), and resemble the actual specimen as nearly as possible. They should be dated and have the student's name in the upper right-hand corner.

By following the procedure given below anyone can make the simple line drawings which are desired in this course. Good results in this mechanical line work can be secured by inexperienced students.

Draw on one side of the paper. First determine how large the drawing is to be, then select a suitable space on the page. Rule this space with very light vertical and horizontal guide lines of a proper size so that the drawing may be made symmetrical. With the ruler reduce or enlarge the length and width of the object so that it will fit the space selected. With very light lines make an outline of the object; measure with the ruler to determine the location, using the proportion established above. When the light lines are in good proportions and the details are as nearly like the object as you can get them, erase the light lines until you can barely see them; then go over them making the final lines, firm, continuous and clear. Every line on the drawing should represent a structure present on the object.

Label the drawings fully. Number each plate and figure. In labelling the figures draw a straight line parallel to the top of the sheet, out from the structure to be labelled and then write or print the label on this line. Label all structures, even those labelled in previous drawings.

### 3. Dissecting.

Dissection consists in separating the parts of an animal in such a way as to make them visible. It does not refer to the cutting of animals into pieces. The parts should be left as intact as possible. Follow the directions and do not cut anything or remove anything unless specifically directed to do so. Clean away the connective tissue binding and concealing the parts by use of blunt instruments such as the probe or forceps, or by the fingers. **Avoid** use of the scalpel and scissors; when using these instruments, make short cuts and remove small portions at a time. Do not cut the animal unnecessarily, but separate the parts. Improper initial dissection will render the study of the later parts very difficult.

### 4. Care of Specimens.

Each student will be furnished with the necessary specimens. Do not discard any animal until directed to do so. The specimens will be kept in a common container. A num-

bered metal tag will be given to you for identification. When ready to leave the laboratory wrap the animal in cheese cloth and tie it with a cord. Have the cord long enough so that one end can be left to which a tag bearing your name may be tied. When first starting work on a specimen wash it off in water. Always keep the specimen moist because drying ruins the animal for dissection. Specimens which are not properly cared for become difficult to dissect.

5. Corrections to Drawings.

When you have finished a plate before leaving that section of the manual refer it to the instructor at a convenient or stated time and have it checked for errors. Much of the drawing work is checked in the laboratory as dissection proceeds.

# CHAPTER II

## EXTERNAL CHARACTERISTICS

### I. GENERAL CONSIDERATIONS.

#### 1. The Skate.

The skates are elasmobranch fishes which are highly modified in external form and proportions. They demonstrate, however, the characteristics of the vertebrates in most of their morphological details. The little skate, *Raja erinacea* Mitchill, matures at a smaller size than the other common Atlantic skate, the big skate, *Raja diaphanes* Mitchill, and is the one upon which these directions are based specifically. Most skates have a very similar anatomy and may be dissected by the same procedure as is given here.

The little skate is found along the coastal waters off the Atlantic seaboard of America from Nova Scotia to Virginia. For further information on skates read the section on elasmobranchs in "Fishes" by David S. Jordan and "Fishes of the Gulf of Maine" by H. B. Bigelow and William W. Welch. The following key is compiled from the latter book.

Determine what species your specimen is from the key. Work out the identification of other specimens on demonstration.

#### 2. A Key to the Skates and Rays Common to the American Atlantic Coast.

a-1. The tail without a long dorsal spine.

b-1. No distinct caudal fin but two small dorsal fins on the tail. The skates, Family *Rajidæ*.

c-1. A row of large thorns on the midline of the back either on the rear part of the disk, or on the tail, or on both.

d-1. The anterior angle of the disk is much greater than a right angle. The entire dorsal surface more or less covered with spines, the midline having large spines behind the shoulders. The Prickly Skate, *Raja scabrata* Garman.

d-2. The anterior angle of the disk roughly a right angle, the snout hardly projecting, relatively blunt. Dorsal surface with few, but large thorns, the midline having large spines on the disk and the tail. The outer corners of the disk are bluntly angular. Brier Skate, *Raja eglanteria* Bosc.

d-3. The anterior angle of the disk roughly a right angle. The thorns are few and small; the midline having thorns on the disk as well as on the tail. Tip of snout sharp-pointed. Outer corners of disk rounded. Rare. Smooth Skate, *Raja senta* Garman.

d-4. The anterior angle of the disk more acute than a right angle. The long, blunt tipped, snout projecting. Midline with thorns only on the tail; all thorns small. Barn-door Skate, *Raja stabuliforis* Garman.

c-2. Without a row of large thorns directly on the midline of the dorsal surface. Several rows may be present on either side.

e-1. About 50 rows of teeth, the dorsal surface brown with dark spots. Little Skate, *Raja erinacea* Mitchill.

e-2. About 90 rows of teeth, the dorsal surface usually with two large, whitish, round spots near the posterior angles of the disk. Spotted Skate, *Raja diaphanes* Mitchill.

b-2. A large trinagular caudal fin and two dorsal fins on the tail. The torpedo. Family Torpedinidae. Electric Skate *Narcacion nobilianus* Bonaparte.

a-2. The tail with a long dorsal spine (the sting-ray).

f-1. A dorsal fin on the tail in front of the long spine. Family Myliobatidae. Cow-nosed Ray. *Rhinoptera quadriloda* Le Sueur.

f-2. No dorsal fins.
g-1. Tail rounded above, without keel. Sting ray, *Dasybatus marinus* Klein.
g-2. Upper side of the tail with a distinct keel posterior to the long spine. Sting ray, *Dasybatus hastatus* De Kay.

### 3. Animal Form.

Vertebrate animals with few exceptions carry themselves in an horizontal plane, their surfaces always retaining the same relative position. These surfaces are indicated with reference to this position. Locate the following regions of the skate: **dorsal,** the back or upper side (posterior in human anatomy); **ventral,** the under side (anterior in human anatomy); **lateral,** the sides right and left (throughout this manual right and left refer to the skate's and not to the student's right or left); **anterior, cephalic,** or **cranial,** the head end (superior in human anatomy); **posterior,** or **caudal,** the tail end (inferior in human anatomy); and **median,** the middle.

Adverbs may be formed by substituting a "d" for the last letter of these terms with the meaning "in the direction of" as caudad meaning towards the tail. Anterior and posterior may be employed to indicate the relative positions of structures with reference to the head or tail, for example the pelvic fins are posterior to the pectoral fins.

The head, trunk, tail, and neck when present, make up the **axial** part of the animal while the fins or limbs make up the **appendicular** portion of the animal.

Drawing 1. Draw the outline of the skate from the dorsal viewpoint indicating the above named surfaces and regions.

### 4. Imaginary Planes and Axes.

Determine these imaginary planes and axes of the skate.

a. The **sagittal** plane or section is any vertical plane

passing through the body longitudinally. The **median** plane is that sagittal plane which passes through the mid-line of the body and divides it into two mirrored or identical halves.

b. The **horizontal** or **frontal** plane or section is any horizontal plane passing longitudinally through the body. It is at right angles to the median plane and parallel to the dorsal and ventral surfaces.

c. The **transverse** or **cross section** or plane is that plane which passes through the body at right angles to the sagittal and the horizontal planes.

d. The **longitudinal** or **anteroposterior** axis is any axis which is in the median plane extending from the head to the end of the tail.

e. A **sagittal** or **dorsoventral** axis is any axis in a sagittal plane and passes from the dorsal to the ventral surface.

DRAWINGS 2, 3, 4. Diagram the planes and axes of a vertebrate and demonstrate them using plastic clay.

5. SYMMETRY.

An animal which has symmetry may be divided by a line or plane in such a way that one of the halves will be a mirrored image of the other. Asymmetrical animals cannot be so divided. The opposite like parts of a symmetrical animal are called **antimeres.** There are three well marked types of symmetry in animals, **universal, radial** and **bilateral.** The embryo of many vertebrates passes through all stages of symmetry; universal symmetry in which no opposite sides are different (blastula); radial symmetry in which opposite ends are different (gastrula); and bilateral in which opposite ends and two opposite sides are different, which is the symmetry of adult vertebrates.

There is but one plane of symmetry in a bilateral animal. The **median sagittal plane** is the one and only plane that

will divide the animal into two mirrored halves. The structures of a vertebrate therefore are either **paired,** in which case they are located symmetrically on each side, or are **unpaired,** in which case they are located in the median plane.

## II. EXTERNAL STRUCTURES.

### 1. Parts of the Body.

The body is divided into a greatly flattened anterior portion consisting of the **head** and the **trunk,** and a slender posterior portion, the **tail.** This broad, flat form is characteristic of bottom-feeding fishes and is obtained by a shortening of the dorsoventral axis. For a generalized body form see the shark which is on demonstration.

### 2. Fins.

The skate has median or unpaired fins and paired fins. Locate the two small **dorsal** fins on the tail; a pair of **pectoral fins** which are enormously enlarged forming the lateral expansions of the trunk; and a pair of **pelvic fins** which are posterior to the pectoral fins and continuous with them in some species. The pelvic fin will be found to consist of two lobes, one of which in the males bears a long **clasper** which is grooved on its posterior lateral margin and is used in mating. Only a trace of the **caudal** fin will be found at the end of the tail. For the normal fin development see the shark on demonstration.

### 3. Head.

The head is very greatly flattened and its margins are continuous with the pectoral fins. The head terminates in a **rostrum.** A pair of **eyes** without lids is located on the dorsal surface, and behind each eye is a **spiracle** or **first gill-slit.** On the anterior face of the spiracle is a valve

which is marked by parallel ridges representing a rudimentary gill. The **mouth** is on the ventral side and is limited by the tooth-bearing upper and lower **jaws.** Anteriorly from the corners of the mouth running to the **nostrils** is a flap, the **nasofrontal process,** under which is the **oronasal** groove. This groove foreshadows the development of the closed passage found in the more specialized vertebrates. There are five pairs of **gill-slits** posterior to the mouth. These may be designated as the second, third, fourth, fifth, and sixth gill-slits.

4. Tail.

The **cloacal aperture** or **anus** (the term **anus** should be restricted to the opening of the digestive tract) is located between the bases of the pelvic fins. **Abdominal pores** which lead into the body cavity are located just posterior to and on each side of the aperture. Their use is obscure, but they may represent the remains of segmental ducts.

5. The Skin.

A. *The Placoid Scale.*

The skin is quite tough. It has scattered **placoid** scales whose projecting **spines** are very evident. The placoid scale occurs in the elasmobranch fishes and is regarded as the ancestral structure from which true vertebrate teeth were developed. Remove a piece of skin containing one placoid scale. Clean away the skin and expose the complete scale, which consists of a **basal plate** embedded in the skin, and a projecting curved **spine.** Within the spine is a **pulp cavity,** which may be located by probing with the point of a needle at the center of the under side of the basal plate. The coating of the spine is composed of **enamel.** The basal plate and the interior of the spine are composed of **dentine.**

B. *Homology and Analogy.*

The structure and mode of origin of placoid scales and the teeth of all vertebrates are exactly the same, although their function and superficial appearance is very different. Teeth and placoid scales then are said to be **homologous structures.** **Analogous** structures are those structures which resemble each other in superficial appearance or in function but which have different origins. The lining of the mouth cavity is composed of skin which has become turned in, consequently the placoid scales which were carried with it into the mouth cavity have been **adapted** to new purposes and the homologous parts have begun a **divergence.** Analogous structures result from a **convergence** which is often the result of the action of similar conditions upon structures of different origin. Identify the following parts on the longitudinal section of a vertebrate tooth; the **crown,** homologous with the spine; the **root** homologous for the most part with the basal plate; the **pulp cavity,** a central space, filled in the living tooth with the **dermal papilla** of connective tissue, blood vessels, nerves, etc.; the **dentine,** a bone-like substance composing most of the tooth and the **enamel** the shiny outer coating of dentine on the crown. Compare part for part the placoid scale and the vertebrate tooth.

The theory of evolution accounts for homologous structures by its central concept that all vertebrates have been derived from a common ancestor. Consequently homologous structures would be the result of the inheritance of modifications of a common primitive structure.

Drawing 5. Draw the skate from the ventral surface.

Drawing 6. Draw a section of a placoid scale and beside it diagram the tooth of a vertebrate.

# CHAPTER III

## THE RESPIRATORY SYSTEM

The skate obtains its oxygen for respiration from the water. A muscular expansion of the mouth and pharynx causes water to enter the oral cavity through the spiracle and the mouth. The spiracle is located dorsally in the skate and so is free from the sand and mud of the bottom. Contraction of the muscular expansion of the mouth and pharynx causes the water to be expelled through the gill slits. In so doing the water passes over the gill filaments where the oxygen is taken on by the blood.

1. THE MOUTH AND PHARYNGEAL CAVITY.

Make the following incisions very carefully as success in much of the future work depends upon this initial dissection. Work a blade from a pair of heavy scissors or a knife into the **left** (skate's left) corner of the mouth and cut the jaw in the direction of the gill-slits; continue cutting the entire tissue between the mouth cavity and the exterior towards the gill-slits; extend the cut along the median margin of the gill-slits and continue it posteriorly to the heavy cartilaginous bar of the pectoral girdle; cut through this bar with the scalpel; then turn the 7-shaped flap formed over to the side. This exposes as a continuous cavity the mouth and pharynx. In very rare cases the stomach is accidentally everted into the cavity and care should be taken not to injure it.

The anterior part of this cavity, which is between the

mouth and gill arches, is the **oral** or **mouth cavity.** It is limited in the front by the upper and lower **jaws** which bear the **teeth.** The tongue is absent in the skate. The lower and upper jaws are the two halves of the first or **mandibular gill-arch.**

The posterior part of the cavity is the **pharynx.** It converges at its posterior end into the **esophagus,** which connects directly with the stomach. Probe into the esophagus. Six **internal gill-slits** break the lateral wall of the pharynx. The first, which is much modified, is the **spiracle,** which is an opening in the roof of the mouth just posterior to the mandibular arch. Locate the other five gill-slits.

The internal gill-slits communicate with large **visceral pouches** which open to the exterior through the external gill-slits. Run a probe through the internal gill-slit of the right side, pushing it into the visceral pouch and out the external gill-slit. This is the course which the water takes during respiration. The **visceral arch** is composed of the tissue between two successive visceral pouches.

DRAWING 7. Draw the mouth cavity and the pharynx.

## 2. VISCERAL ARCHES.

Examine the parts of the visceral arches where they have been cut. The **interbranchial septum** is the central portion of the arch which extends to the outer surface. The spaces between successive septa on the outer surface of the body form the external gill-slits, and those on the inner surface of the body the internal gill-slits. The septum bears plates and folds on its sides, the **branchial** or **gill filaments.** These extend into the visceral pouches. The filaments on one face of the septum form a **half-gill** or **demibranch.** The two demibranchs of a septum make up an entire **gill** or **branchia.** Count the demibranchs and determine whether

any are missing. On each visceral arch cross-section note the cartilaginous **gill-arch** and in the septum towards the outer surface from the gill-arch are the cartilaginous **gill rays.** The cut end of the blood vessel, the **afferent branchial** vessel, is located just external to the center of the gill-arch. This vessel brings the non-aerated blood to the gill. On either side of the gill-arch is another blood vessel, usually injected with a yellow colored paste. These are the **efferent branchial** vessels. Small branches of these will be found in the gill filament. All of these efferent branchial vessels collect the aerated blood and, as will be determined later, they unite to form the dorsal aorta.

**DRAWING 8. Draw a cross-section of the entire visceral arch.**

# CHAPTER IV

## THE COELOM, DIGESTIVE SYSTEM, AND MESENTERIES

### 1. The Coelom and Its Walls.

Make an incision through the body wall of the skate just anterior and to the left of the cloaca; run the incision towards one side until the lateral wall of the cavity is reached and then continue it forward along this margin to the pectoral girdle. Do the same for the other side, starting at the original incision. Leave the floor of the body wall attached to the girdle. Be careful not to injure the organs within the cavity.

The body cavity of the vertebrates is the **coelom,** which in its early stages is a continuous cavity extending the entire length of the trunk region. In the adults of all vertebrates this coelom is divided into at least two parts by the formation of a transverse septum at the anterior end. This septum separates the heart from the rest of the body organs and will be located and studied later. The greater part of the coelom which has just been opened is designated as the **pleuroperitoneal cavity.** This cavity is partially subdivided by certain mesenteries. It communicates with the exterior through the **abdominal pores.** Probe into these pores.

The wall of the coelom is made up of these parts; the **skin, muscle,** and a smooth shining inner membrane, the **pleuroperitoneal membrane.** This membrane is divisible into three categories; the **parietal peritoneum,** which is that

part lining the inner surface of the body wall; the **mesenteries** or **ligaments**, the double-walled continuations of the peritoneum from the mid-dorsal or mid-ventral line running to the organs of the body cavity; the **visceral peritoneum** or **serosa** of the organs, formed from the two layers of the mesenteries which separate and surround the organs.

2. The Pleuroperitoneal Viscera.

The **viscera** or **organs** are exposed by the opening of the pleuroperitoneal cavity. The organs cannot be said to be in the cavity since they are completely separated from it by their peritoneum and its extensions the mesenteries. They appear as if they had been let down into the cavity from the dorsal wall, by the peritoneum, while still surrounded by it. They are thus suspended in the cavity.

Drawing 9. Make a line diagram of an imaginary section through the anterior end of the pleuroperitoneal cavity showing body wall, parietal peritoneum, visceral peritoneum of the intestine, and the mesentery suspending it.

3. The Digestive Tract.

A. *External Aspects.*

The digestive tract consists of a thick-walled tube extending from the anterior end to the posterior end of the body. It is differentiated into various regions having dissimilar functions. Part of the digestive tract has already been encountered, the **mouth,** the **pharynx** and the **esophagus.**

In the following study do not disturb the position of the internal organs more than is absolutely necessary and do not break them apart or separate them from the body wall. Occasionally the stomach is accidentally everted into the mouth cavity. In such cases it should be pulled back into position.

At the anterior end of the cavity is the **liver,** which is composed usually of three lobes of about the same size. In the angle between the median and the right lobes of the liver is the **gall bladder.** Dorsal to the liver and on the skate's left side is the j-shaped **stomach.** It is continuous with the esophagus and is partly concealed by the lobes of the liver. The anterior part of the stomach is the **cardiac** portion while the smaller bent portion is the **pyloric** region. The latter terminates the stomach in a sharp constriction, the **pylorus.** The remainder of the digestive tract to the **anus** is the **intestine.** The first section of the intestine just beyond the pylorus is the **duodenum.** Beyond the duodenum the intestine becomes enlarged and the lines of insertion of the **spiral valve,** which is within the intestine, are visible.

Near the posterior end of the intestine is the small cylindrical **rectal gland** which is attached to the intestine by a short duct. The intestine is divisible into two parts, the **anterior intestine** (small intestine) and the **posterior intestine** (large intestine). The place of separation is at the rectal gland. The terms small and large intestine may be given to these parts out of consideration for their homology, but in the skate they are just the reverse in actual size. The posterior intestine is very short and opens by the **anus** into the terminal chamber, the **cloaca,** which in turn opens to the exterior by means of the **cloacal aperture.**

B. *The Derivatives of the Digestive Tract.*

Along the digestive tract are numerous organs and **glands** which have been derived from the tract. Some of these will be considered here. A series of derivatives have already been encountered, including the visceral pouches and the gills.

The **thyroid gland** is an outgrowth from the ventral wall

of the pharynx and will be located later when it is exposed during the study of the circulatory system.

The **liver** is one of the largest of the glands and is an outgrowth of the wall of the intestine. It is composed of three lobes. The **gall bladder** is a greenish or yellowish transparent sac located between its right and middle lobes. The **common bile duct** should be located in the mesentery just below the gall-bladder and followed forward. It will be found to originate at the gall-bladder. A short **cystic duct** leads from the gall-bladder and a **right** and **left hepatic duct** join it as it passes into the common bile-duct. Posteriorly it passes to the dorsal side of the duodenal wall and runs a short distance caudad imbedded in the wall before it penetrates the cavity of the duodenum.

The **pancreas** arises from several outgrowths of the intestine proper. The **ventral** lobe is a white body in the curve of the duodenum and is continuous with the **dorsal** lobe which is dorsal to the duodenum. The **pancreatic** duct empties into the intestine on the opposite side from the entrance of the bile-duct. It will be found imbedded in the posterior margin of the ventral lobe of the pancreas. Split open the intestine near this point and try to locate the entrance of the pancreatic and bile ducts.

### C. *The Internal Aspects of the Digestive Tract.*

Cut open the stomach and place the contents in a dish. The Little Skate is omnivorous. Hermit and other crabs, shrimps, worms, amphipods, ascidians, bivalve mollusks, squids, small fishes, and other animals may be present in the stomach.

Cut open the anterior intestine along one side just between the large longitudinal blood vessels found on its wall. The **spiral valve** is its chief structure. It consists of a fold of the intestinal wall spirally coiled so as to form a series

of incomplete overlapping cones. This formation greatly increases the digestive and absorptive surface of the intestine and makes a long intestine unnecessary.

D. *The Spleen.*

The **spleen** is a dark-colored organ located on the dorsal side of the stomach at its bend. It is not a part of the digestive system, but belongs to the category of lymph glands of the lymphatic system. Its function appears to be the destruction of foreign particles, bacteria and the like, and the addition of white blood corpuscles to the blood circulation.

DRAWING 10. Make an outline drawing of the digestive tract, its derivatives and the spleen.

E. *The Mesenteries.*

The viscera are suspended and held in place by membranes, the **mesenteries** or **ligaments** which are the extensions of the pleuroperitoneum. The dorsal mesentery is incomplete in the skate. It extends from the dorsal wall to the anterior part of the stomach and the posterior part of the esophagus as the **mesogaster.** It incloses the spleen in an extension from the stomach, the **gastrosplenic.**

A remnant, the lesser omentum, is all that is left of the ventral mesentery, which typically is an outfolding from the median ventral wall. It extends from the right side of the stomach to the liver and is roughly divisible into two parts: the **hepatoduodenal,** which extends from the duodenum and which contains the bile duct and blood vessels, and the **gastrohepatic,** which extends from the stomach to the liver. The **falciform** ligament is another remnant of the ventral mesentery and is located at the anterior end of the liver, extending from the midventral surface of the liver to the midventral line of the body wall.

# CHAPTER V

## THE UROGENITAL SYSTEM

### 1. The Urogenital System.

The excretory system of vertebrates consists of certain excretory organs with their ducts. The reproductive system consists of a pair of gonads or sexual glands and their ducts. The reproductive glands use the ducts of the excretory system to transport their product of germ cells to the exterior, hence these two systems are generally quite closely united and are considered together as the **urogenital** (urinogenital) **system.** Work out the urogenital system of your specimen, then study the dissection of a specimen of the other sex which is being prepared by another student.

Males may be distinguished from the females by several characters. Claspers are present on the male. The greater part of the sides lacks scales in the male. There are also fewer rows of spines along the middle of the back and tail. The scales on the margin of the head are much enlarged. Two rows of erectile spines are present on the lateral expansion of the trunk (about one inch from the margin). These can be erected and lowered into depressions in the skin. In the females, scales are present over the sides of the body, several rows are present on the dorsal surface of the tail and the dorsal median part of the body. The female has no erectile spines.

During the development of vertebrates there are three more or less distinct excretory organs or kidneys. (1) The **pronephros** is present in the embryonic stages of fishes and

amphibians when it is probably functional as an excretory organ. They persist in adult lampreys and a few fishes, while in reptiles, birds and mammals they appear during embryonic stages as transient structures without function. (2) As the pronephroi degenerate a second excretory organ is developed, the **mesonephros** (pl. mesonephroi) or **Wolffian body.** The mesonephros is the kidney of adult fishes and amphibians and appears in the embryos of reptiles, birds and mammals when it is functional until the formation of the (3) **metanephros or** true kidneys of the adult reptiles, birds and mammals.

A. *The Female.*

The main portion of the kidney of the female skate consists of rounded lobes (masses about 30 x 10 mm.) which are located against the dorsal wall of the body cavity at the extreme posterior end and on either side of the median axis. Carefully remove the pleuroperitoneum which covers the ventral surface of the kidney on the left side starting at its lateral margin and proceed towards the midline. This reveals the **caudal mesonephros.** An anterior extension, the **cranial mesonephros** is nearly degenerate in the female, but may be noticed as a brownish diffuse tissue extending from the anterior end of the caudal mesonephros.

In the male skate it is much better developed and extends forward as a light-colored flat body on either side of the median axis.

On the median surface of the caudal mesonephros are several ducts, the **accessory mesonephric ducts** (to avoid later difficulty the term ureter should be applied only to the excretory duct of the metanephros). These ducts may best be located by dissecting away, with blunt end of probe or scalpel, the connective tissue which extends from the

mesonephros to the dorsal anterior wall of the cloaca. The ducts are those white tubes running in this tissue which do not break or cut as readily as the connective tissue. They extend medially and forward and enter a chamber, the **urinary sinus,** situated on the dorsal surface of the anterior end of the cloaca. Remove the connective tissue in this region. The two sinuses unite to form a common chamber, the **urinary vesicle** (it is not a true bladder or homologous with that organ since it is the enlarged termination of the mesonephric ducts rather than an evagination of the ventral wall of the cloaca). Make a small incision in the sinus and run the probe into its entrance to the vesicle. Probe through the vesicle and into the opening in the mid-dorsal wall leading into the cloaca. The **Wolffian ducts** (degenerate and functionless for the most part in the female) of the cranial mesonephros are slender tubes which extend anteriorly from the urinary vesicle lying on the dorsal surface of the strong white portion of the mesenteries. The remainder of the excretory system (cloaca and cloacal aperture) is in common with the digestive system. Cut open the extended cloaca along the median ventral line and also open the intestine a short distance. Note the opening of the intestine, the **anus,** into the ventral part of the cloaca and the horizontal fold which separates this from the dorsal or urogenital portion. Cut into the latter by cutting forward through this fold. The **urogenital opening** in the median dorsal wall is half way between the openings of the oviducts which are on either side. A probe may now be run from the opening made in the urinary sinus through the urinary vesicle and into the cloaca by way of this urogenital opening.

The **ovaries** are two soft bodies (masses about 25 mm. x 40 mm.) which contain large **ova** or eggs and are situated in the back portion of the anterior half of the pleuroperi-

toneal cavity. Each ovary is attached to the structures dorsal to it by a mesentery, the **mesovarium.** Dorsal to the ovary is the **oviduct,** an enlarged tube which is connected with it only by mesentery. Dissect away this mesentery. Trace one of the oviducts forward and notice in your specimen or in a demonstration specimen that its narrow anterior portion passes along the dorsal coelomic wall, curves around the anterior dorsal margin of the liver and unites with its fellow from the other side, where is located the **ostium,** a wide funnel-shaped opening for receiving the eggs after they break out from the ovary into the coelom.

Trace the oviduct caudad and notice an enlargement of the tube, the **uterus.** At its beginning is a bilobed mass, the **oviducal gland,** which secretes the **horny case** (see demonstration) in which the eggs are contained. Egg cases will often be found in the uterus of the skates being dissected.

DRAWING 11. Draw the female urogenital system.

B. *The Male.*

The **testes** in which the sperm cells are developed are oval flat bodies (about 60 mm. x 20 mm.) attached to the more dorsal structures by mesenteries, the **mesorchia.** The kidney or excretory organ is like that of the female. Dissect it out after the manner outlined above for the female. The mesonephric or Wolffian ducts are well developed tubes running posteriorly along the ventral faces of the **cranial mesonephros.** They serve as a passageway for the sperm cells. They are greatly convoluted tubes located near the median line.

The testis is connected with the cranial mesonephros by means of delicate ducts, the **vasa efferentia,** which run in the mesorchium. These vasa efferentia connect with tubules of the mesonephros. The sperm tubules of the mesonephros connect with the Wolffian duct. Trace the duct and notice

that it enlarges on the surface of the caudal mesonephros, forming the **seminal vesicle** (best developed in adult specimens). Remove the pleuroperitoneum from the ventral surface of the caudal mesonephros and find that at the posterior end and at the sides of the cloaca that the seminal vesicle opens into the lower end of the sperm sac. These lead into the urogenital sinus by a common opening.

Split open the cloaca (in the male it is much smaller than in the female) ventrally and notice on the dorsal wall the projecting **urogenital papilla.** The urogenital sinus leads into the cloaca at the tip of the urinary papilla. Run a fine probe into the opening of the sinus and trace the entrance of the sac and seminal vesicle. The sperm cells pass out through the cloacal aperture and along the grooved lateral margins of the claspers.

The **accessory mesonephric** ducts are similar to those of the female described above and are located by following the same procedure. In the male skate several of these accessory ducts will be found coming from the median side of the mesonephros and going into the sperm sac.

Drawing 12. Draw the male urogenital system.

# CHAPTER VI

## THE CIRCULATORY SYSTEM

In vertebrates the circulatory system is composed of two series of tubes, the **lymphatic** and the **blood-vascular** systems, which inclose fluids that circulate. The **blood-vascular** system is commonly termed the **circulatory system.** It consists of a set of branching continuous tubes which form a closed system and are unconnected with any other system.

1. The Pericardial Cavity.

Remove the skin from the ventral surface of the region posterior to the mouth. Start with an incision at the pectoral girdle and work forward between the gill-slits of the two sides. Remove with the forceps the layers of visceral muscle found below the skin until a membrane, the **parietal pericardium,** in the posterior median region is uncovered. Remove this membrane and expose the pericardial cavity, within which is the **heart.** The cavity may be better revealed if the tissue along the anterior face of the girdle is removed. This should be cut away where necessary, care being taken not to injure the heart.

The pericardial cavity is a part of the coelom. The other part, the pleuroperitoneal cavity has been studied. The two parts are separated by a membrane, the **transverse septum,** which forms the posterior wall of the pericardial cavity.

The septum is not complete since an opening, the **pericardio-peritoneal canal,** which will be pointed out later,

connects the cavities. The septum is formed as a bridge, enabling the dorsal blood vessels to pass to the heart, which is ventral in position.

2. External Aspects of the Heart.

The heart is attached at its posterior and anterior ends by deflections of the parietal pericardium, which may be located by lifting up the heart. The **visceral pericardium** is an extension of this, which covers the heart and is indistinguishably fused with its wall.

The wings of the **sinus venosus** may be located on either lower corner of the main mass of the heart as thin-walled wide tubes. Make a very small incision in the right wing and insert the probe and run it towards and into the main mass of the heart. The wings of the sinus venosus are in the transverse septum. Non-aërated blood from the various parts of the body is returned to the heart through the sinus venosus.

During development the heart is at first a straight tube, but later it becomes bent upon itself dorso-ventrally in the form of a letter S. The walls of the tube are differentiated into chambers which should be located on the exterior. The first chamber is the sinus venosus already located. The thin-walled second chamber just anterior to the sinus venosus and on the dorsal side of the heart is the **auricle** or **atrium**. It expands on each side of the anterior portion of the heart so that a portion of it may be seen from a ventral viewpoint. The third chamber is the thick-walled, heart-shaped, **ventricle**. The posterior lateral end of the ventricle is the **apex**, the anterior side is the **base**. The fourth chamber is the **conus arteriosus**, a heavy-walled tube which originates at the base of the ventricle and penetrates the anterior pericardial wall. The blood, all of which is non-aërated, circulates through the chambers of

the heart in the order mentioned. The **internal structures** of the heart will be considered later.

DRAWING 13. Sketch the heart from the ventral viewpoint.

3. THE VENOUS SYSTEM.

Veins are those blood vessels through which blood is returned to the heart. There are three kinds of veins in the vertebrates: (1) The **systemic veins** which empty directly into the heart; (2) the **portal veins** which carry the blood to a system of capillaries (e.g., in the liver), where it is brought together in systemic veins and delivered to the heart; (3) the **pulmonary veins** in vertebrates with lungs which bring the aërated blood back to the heart from the lungs.

A. *The Systemic Veins.*

The dissection of the veins is the most difficult part of the entire study of the skate. Follow the directions very closely and most of the system will be clearly unfolded. Refer to the figure to aid in your organization of this system. Many of the veins of the skate are not sharply defined vessels, but are large spaces in the tissue, without very definite walls and are more correctly called **sinuses.**

The systemic veins enter from both posterior corners of the dorsal side of the heart by way of the sinus venosus, which has already been pointed out. The central portion of the sinus venosus, which receives the two tubes from either corner, is attached to the transverse septum by a sheet of connective tissue which should be broken away carefully. Trace out the right side of the sinus venosus, which is buried in the transverse septum, until it disappears dorsal to the pectoral girdle cartilage. Follow the sinus laterally by carefully shaving away the cartilage and the surrounding tissue. With fine scissors cut open the ventral

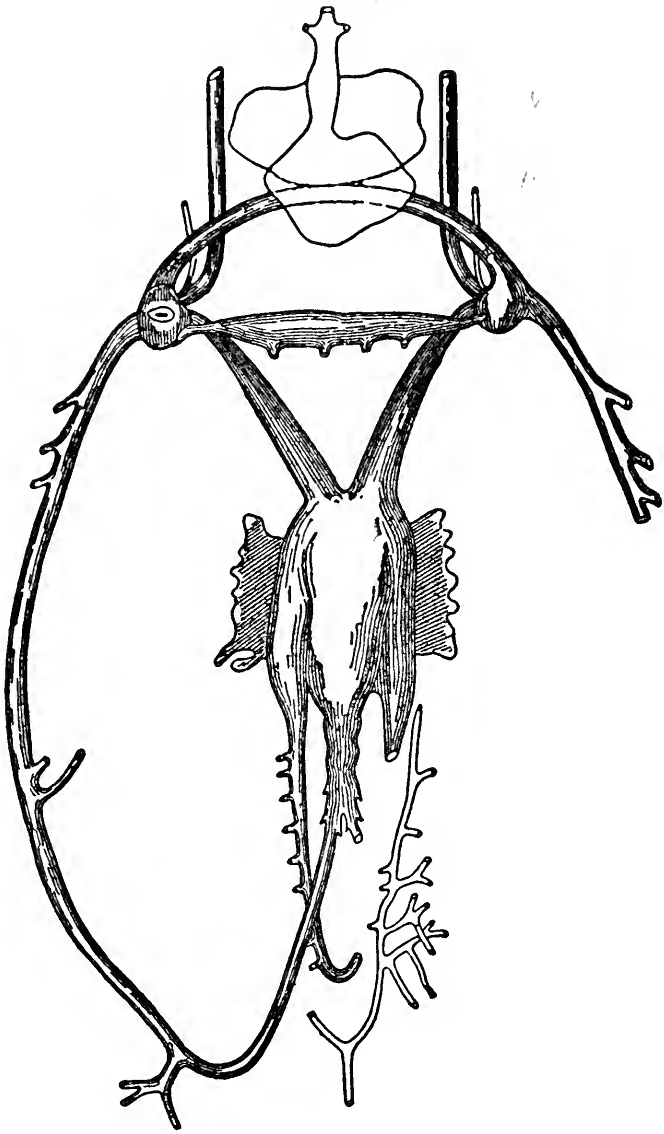

FIG. 1. The ventral aspect of the venous system of *Raja nasuta*. (Redrawn from Parker, *Zootomy*, Macmillan and Co.)

wall of the sinus in a crosswise direction. Leading directly into the sinus is the chamber or tube, the **common cardinal** or **duct of Cuvier,** which bends towards the dorsal surface.

All of the systemic veins carry blood to this common cardinal vein.

There is a slight fold at the juncture of the sinus and the common cardinal vein near which is the rather small entrance of the **inferior jugular**, a vein which collects blood from the walls of the pericardial cavity and the floor of the mouth and pharyngeal cavities. Use a bristle to probe into it. The **hepatic sinus** enters through the posterior wall of the common cardinal. Its main chamber is a large space situated between the anterior end of the liver and the transverse septum. Locate this chamber and cut it open. It has an outlet towards both right and left common cardinal veins. Several small **hepatic veins** enter it from the liver.

The **pericardio-peritoneal canal** runs through the center of this sinus. It will be remembered that this canal connects the two otherwise separated parts of the coelom. Refer back to Chapter IV.

The **posterior cardinal** vein enters the common cardinal through the dorsal part of the posterior wall. Probe into this part of the common cardinal and towards the midline of the dorsal wall of the pleuroperitoneal cavity. The posterior cardinal continues as a large space located on the dorsal side of the testes in the male and on the dorsal side of the oviduct in the female. Posteriorly it will be found to unite with the one from the other side, forming a **median sinus** which is directly connected through its ventral walls with the **genital sinus**. The latter originates as large spaces about the gonads. The median sinus separates again posteriorly into two veins proceeding on the medial side of the kidneys, where they are again united.

The **anterior cardinal** sinuses return the blood from the anterior part of the body and head. Run the probe from the common cardinal towards the dorsal side of the skate,

turn the skate over and locate the end of the probe. Make a longitudinal incision at the end of the probe and run it forward to the eye. This exposes the anterior cardinal sinus, which is a smooth-walled elongated cavity situated between the dorsal ends of the visceral pouches.

A branch of the **brachial vein** may be located on the dorsal surface. Make an incision along the medial face of the anterior cartilage of the pectoral fin and locate this vein. It runs into the common cardinal vein.

Within the pleuroperitoneal cavity a few other veins may be located. On the lateral wall is the **lateral abdominal vein** which receives a **parietal** branch from each myoseptum. It originates near the cloaca. It passes along the internal surface of the pectoral fin cartilage and extends to the common cardinal vein. **Brachial** veins will be found joining the lateral abdominal vein. One may be located on the posterior side of the pectoral girdle cartilage. There are others. The largest of the **iliac** veins will be found along the posterior side of the cartilage of the pelvic girdle. The iliac veins come from the pelvic fin.

DRAWING 14. Outline the systemic veins.

B. *The Portal Systems.*

In the skate there are two portal systems, the **hepatic portal** and the **renal portal.** The hepatic portal system collects the venous blood from the various parts of the digestive tract and spleen and carries it into the liver, where it breaks up into a network of capillaries which are collected later and enter the hepatic sinus.

a. The Renal Portal System. Study the renal portal system from the figure. It consists of a **caudal vein** which collects the blood from the caudal region and runs forward to the cloacal aperture, where it forks into the two **renal portal** veins extending to the ventral side of the kidney

and there giving off branches. These capillaries unite to form veins which connect with the posterior cardinal vein.

b. The Hepatic Portal System. In many of the specimens the hepatic portal system shows up as dark-blue tubes, the color being due to the presence of blood in the veins. If your specimen does not show the veins clearly in the region of the stomach and the intestine another specimen will be loaned to you from the general supply. The veins are often near the yellow-colored arteries.

The main hepatic vein is located in the hepatoduodenal ligament near the bile duct. It receives branches from the digestive tract and its derivatives. There are three main tributaries. (1) The **gastric vein,** which enters from the left side, coming from the right margin of the stomach and having a ventral and a dorsal vein from the spleen. (2) The **lienomesenteric** vein enters the hepatic vein as the middle vein. It has two main tributaries; a **posterior mesenteric** from the left side of the intestine arising at the end of the rectal gland and receiving branches from the spiral valve attachments and the pancreas; and a **splenic** from the right or medial end of the spleen. (3) The **pancreatico-mesenteric** joins the hepatic vein from the right side, coming mainly from the pancreas. Its main tributaries are the **anterior mesenteric** from the region of the duodenum, and a **posterior gastric** from between the pylorus and the bend of the stomach.

DRAWING 15. Outline the hepatic portal system including the digestive system with dotted lines.

## 4. THE ARTERIAL SYSTEM.

### A. *The Ventral Aorta and the Afferent Branchial Vessels.*

These arteries are located in the tissue of the floor of the mouth. They are filled with blood, which gives them a

**dark color.** Remove the skin and pick away the tissue and muscle from the region between the anterior end of the pericardial cavity and the lower jaw. Dissect away and expose the vessels, starting just anterior to the heart.

a. The **ventral aorta** is a continuation of the conus arteriosus and is on the median ventral line. Trace it out on the left side and expose the **afferent branchial arteries.** The first pair of these is given off at the point where the conus arteriosus passes into the ventral aorta. It divides into three branches, which supply the fourth, fifth, and sixth visceral arches and extend into the interbranchial septa, giving off branches to each of the demibranchs.

It is necessary for dissectional reasons to point out here the **coronary arteries** which supply the heart walls with aërated blood. They are yellow in color and should not be injured more than is necessary in the following work. Their connections will be pointed out later.

The second pair of afferent branchial vessels is formed by the bifurcation of the ventral aorta at its anterior end. Follow the aorta forward almost to the lower jaw where the second pair originates.

Trace the left one. It divides into two vessels which penetrate the interbranchial septa of the second and third visceral arches. The embryonic first afferent artery of the first arch, the spiracle, is not persistent in the adult skate probably because there is no functional gill on this arch.

Drawing 16. Draw the ventral aorta and the afferent branchial vessels.

### 5. The Internal Structures of the Heart.

Review the drawing of the heart, number 13. The heart is a modified tube bent dorsoventrally into the various chambers which have been mentioned before. Because of

this bending, which results in an s-shaped structure, the ventricle is brought into contact with and overlies the sinus venosus, and the auricle is brought into contact with and is beneath the conus arteriosus.

First note the distribution of the posterior coronary artery coming from the posterior corners of the pericardial cavity. Their origin will be indicated later.

Remove the heart from the pericardial cavity by cutting it at the base of the ventral aorta and freeing the sinus venosus from the transverse septum. Split open the sinus venosus which leads into the auricle by a **sino-auricular aperture** which is supplied with **sino-auricular valves.** Open the auricle and wash out the blood clot. It opens into the ventricle through the **auriculo-ventricular aperture** which is supplied with **auriculo-ventricular valves.** Open the ventricle to locate these valves. Within the ventricle note the numerous cavities and crevices in the spongy inner wall where the blood is held, and the muscular band, the **columnae carnae.** Open the conus arteriosus which is provided with many pocket-like **semi-lunar valves.** There are three longitudinal rows of valves and five valves in each of the rows. To locate and open these pockets run the point of a probe from the anterior end towards the posterior end.

In the skate, as in all fishes, there is a single circulation through the heart. The heart contains only venous blood, which enters the sinus venosus from the systemic veins and passes through the auricle, ventricle, and conus arteriosus which connects with the ventral aorta, from which the blood is distributed to the gills by means of the afferent branchial vessels. The blood passes through the gill filaments and is aërated. Since the heart contains no aërated blood its walls are supplied by the coronary arteries from the arterial system.

DRAWING 17. Make a drawing of the heart showing its internal structure with arrows to indicate the course of the blood.

## 6. THE THYROID GLAND AND PERICARDIO-PERITONEAL CANAL.

The **thyroid** gland, the secretion of which seems to regulate growth, may now be located as a brownish tissue just behind the lower jaw and immediately ahead of and in the angle of the bifurcation at the anterior end of the ventral aorta.

The **pericardio-peritoneal canals** may also be located now. These canals, it will be remembered, connect the two parts of the coelom, the pericardial and the pleuroperitoneal cavities. In the center of the posterior wall of the sinus venosus there is an opening of moderate size. Probe into this. It leads into a canal, the **pericardio-peritoneal canal,** which passes through the center of the hepatic sinus. It forks into two canals in the ventral wall of the esophagus and opens into the pleuro-peritoneal cavity by small openings. Refer back to Chapter IV.

## 7. THE DORSAL AORTA.

The **dorsal aorta** and the **efferent branchial** arteries will be found on the roof of the mouth and pharyngeal cavity. With the forceps pick off the mucous membrane and expose the arteries which are filled with yellow starch paste injected from the tail. There are three main pairs of efferent branchial arteries. The blood comes from the gills and is collected by the union of the efferent arteries to form a dorsal aorta which extends backward just ventral to the vertebral column.

Trace the efferent branchial arteries towards the gills, removing the cartilage where necessary. Each efferent artery is formed at the dorsal angle of the internal gill-slits by the union of two arteries. A large **post-trematic**

from the demibranch on the posterior side of the visceral pouch (the anterior face of a gill-arch) and a small **pre-trematic** from the demibranch on the anterior face of the visceral pouch (posterior face of the gill-arch). The post-trematic and the pre-trematic completely surround the pouch, forming a loop around the gill cleft, meeting on the ventral side. At the angle of the ventral and dorsal internal surfaces of the gill-arch a cross-branch is located which unites the post-trematic of a gill-arch with the pre-trematic which is parallel and just posterior to it in the same arch.

The **anterior coronary** arteries, the distribution of which has been pointed out, carry aërated blood to the walls of the heart. They arise from the extension around the fourth and fifth gill-slits of certain vessels from the ventral ends of the loops. The **posterior coronary** arteries are distributed along the sinus venosus and originate from a branch of the subclavian which will be encountered later.

The **common carotid** originates at the junction of the post-trematic and the pre-trematic from the most anterior gill pouch as it forms the most anterior efferent artery. Follow it forward. It bends slightly towards the median line and just lateral to the anterior margin of the spiracle it bifurcates, forming the **external carotid** which continues towards the outside, and the **internal carotid** which continues towards the median line, where it meets with its fellow from the other side and passes through the cartilage to the brain.

There is an **hyoidean artery** which arises at about the middle of the pre-trematic of the most anterior efferent branchial artery. Follow it forward and laterally by cutting away the cartilage behind which it passes. It goes to the rudimentary gill of the spiracle and the adjacent muscles. The branches to the spiracle reunite, forming the

**ventral carotid** which passes laterally and over (ventral) to the external carotid and enters the cartilage, later uniting with the internal carotid within the brain cavity.

The two most anterior efferent branchial arteries fuse and just posterior to their union the **vertebral artery** arises which enters the skull and is distributed to the brain and the spinal cord.

The efferent branchial arteries unite in pairs along the median line and form the **dorsal aorta** which proceeds backwards into the pleuroperitoneal cavity.

DRAWING 18. Show the efferent branchial arteries and their various branches.

### 8. THE DISTRIBUTION OF THE DORSAL AORTA.

Trace the dorsal aorta posteriorly by separating the esophagus from the body wall on the left side. A **subclavian artery** is given off to each side between the points where the third and fourth pairs of efferent branchial arteries enter the dorsal aorta. They go to the pectoral fins. Trace the left subclavian. It gives off these arteries: a **posterior coronary** artery, the distribution of which has already been noted; **lateral arteries** along the lateral body wall; and a **ventral abdominal** artery which runs posteriorly as a conspicuous colored artery on the ventral wall; continuing as the **brachial** it is distributed to the pectoral fin.

A little posterior to the origin of the subclavian arteries the **dorsal aorta** is completed. It then passes posteriorly along the mid-dorsal line of the pleuroperitoneal cavity. Find the following branches, doing the work on the left side after turning the viscera over to the left side of the body.

a. Unpaired Visceral Branches. The **coeliac** is the first

to be given off to the viscera. Its chief branches are: the **hepatic artery** to the liver; and the **anterior gastric** divisible into a **dorsal gastric** and a **ventral gastric** of the stomach; the **splenic**; a **gastroduodenal** with a posterior branch to the posterior part of the stomach, the **posterior gastric, pancreatic** branch; and a **duodenal** to that part of the digestive tract.

The **superior mesenteric** artery has its origin just posterior to the origin of the coeliac and sends branches to the pancreas, and spleen, while its main branch continues to the intestine and the spiral valve.

The **inferior mesenteric** artery arises from the dorsal aorta posterior to the superior mesenteric and passes to the rectal gland giving rise to a **genital artery** which passes to the gonads and their ducts.

b. Lateral Visceral Branches. **Renal** arteries are located on the dorsal side of the kidney. Loosen the kidneys from the body wall and expose these arteries. The **genital arteries** already located belong to this category.

c. The Somatic Branches. Several paired parietal arteries branch from the dorsal aorta and pass to the body wall, enlarged examples of which are the subclavian to the pectoral fin and the paired **iliac arteries** to the pelvic fins. The latter arise from the dorsal aorta just anterior to the cloaca and follow a course along the body wall, giving off many branches, some of which unite with the posterior end of the ventral abdominal artery before entering the pelvic fin.

The dorsal aorta continues posteriorly into the tail, where it is known as the **caudal artery**. The injection of yellow paste was made through this artery.

**DRAWING 19. Draw the dorsal aorta and its chief branches.**

# CHAPTER VII

## THE NERVOUS SYSTEM AND THE SENSE ORGANS

### I. THE SENSE ORGANS.

The sense organs are structurally suited to receive sensory impressions from the outside world. They are all connected with the brain. Two rather distinct types of sense organs may be recognized, the much specialized sense organs having many associated structures such as those connected with sight and hearing, and the simpler integumentary sense organs concerned with touch and perception of temperature. Dissection of the brain often ruins the ear and eye. Therefore, it is advisable to study the sense organs first.

#### 1. Integumentary Sense Organs.

A. Several integumentary sense organs are present in the skate. The **ampullae of Lorenzini** occur in five groups on the head. Remove a piece of skin from the ventral side of the head. The pores lead into the **canals of Lorenzini** which end in a very small bulb, the **ampullae of Lorenzini** supplied with white nerve fibers. These organs seem to function in the perception of vibrations and pressure stimuli from the water.

B. The **lateral line** system consists of several canals, chief of which are: the **supraorbital** canal above the eye extending forward at the side of the rostrum; an **infraorbital** canal which separates from the supraorbital back of the spiracle; the **lateral line canal** extending backwards

from the junction of the supraorbital and the infraorbital along the side of the vertebral column to the tip of the tail; the **hyomandibular canal** with various branches. Tubules lead to the surface from all of these canals and may be easily seen in many specimens.

C. The **pit organs** are on the dorsal surface and may be seen with the unaided eye. They are in three groups: a row of five or less under the eye; a row along the back on each side medial to the lateral line canal; and a group medial to the spiracle on each side.

## 2. The Organs of Special Sense.

### A. *The Olfactory Organ.*

There are a pair of olfactory sacs on the ventral side of the rostrum which open to the nostrils, but which have no communication with the oral cavity. Expose the olfactory sac by cutting away the skin just in front of the eye. Then make a cross-section of the organ. Internally there are numerous plates arranged in rows which are covered with an epithelium sensitive to odors.

Drawing 20. Draw the olfactory organ.

### B. *The Eye.*

Expose the eye or **eyeball,** a spherical body, by carefully dissecting away the skin and connective tissue from around the eye. First cut away the skin over the eye, then carefully cut away a little of the cartilage between the eye and the brain and a part in front of the eye. The eyeball is in a cavity of the skull, the **orbit,** to which it is attached by six eye muscles. Four of these muscles may be identified from the dorsal side. Each muscle is attached at its two ends and is more or less free in between. The attached end which is fixed and immovable is called the **origin** while

the attached end which is moved when the muscle contracts is called the **insertion.** The **superior oblique** muscle has its origin at the anterior wall of the **orbit.** The other three are attached to the lateral posterior wall; the most anterior of these being the **internal rectus** with its insertion on the eyeball covered by that of the superior oblique; most dorsally the **superior rectus**; and the one on the posterior side, the **external rectus.** Determine what would be the result of the contraction of each of these muscles.

Raise the eyeball and cut through the **conjunctiva,** a thin layer adhering to the external surface of the eyeball and continuous with the lining of the lower lid. Lift the eyeball and notice the **inferior oblique** muscle originating from the anteriomedial corner of the orbit and the **inferior rectus** from the posteriomedial angle of the orbit. They are inserted together in the middle of the ventral face of the eyeball.

DRAWING 21. Draw the eyeball showing muscles.

Remove the eyeball by cutting through the eye muscles at their insertions. The outermost coat covering the front of the eyeball is the **conjunctiva** which is deflected onto the inner surface of the eyelids. It is a part of the epidermis of the skin and not a true coat of the eye. The outermost coat of the eye ball is the **sclera,** a tough membrane of connective tissue. It is transparent in front, forming the **cornea** to which the conjunctiva is inseparably fused. Cut off the dorsal side of the eyeball and study under water. Note the **crystalline lens** which aids in focusing the light, the black **choroid coat** internal to the sclera which darkens the interior of the eyeball, and internal to the choroid coat is the greenish layer, the **retina** which is often collapsed. The retina is an outpushing of the brain containing the rods and cones which can be stimulated by the light. Follow

the choroid coat to the front of the eye where it separates from the cornea, forming a black curtain, the **iris,** which may be seen through the transparent cornea and in the center of which may be seen the opening or **pupil.**

The iris divides the cavity of the eyeball into two cavities, an external cavity the **anterior chamber** between the iris and the cornea and the **vitreous humor cavity** between the lens and the retina. The anterior chamber is filled with the **aqueous humor** while the vitreous humor cavity contains in life a gelatinous **vitreous humor.** In life the lens is attached to the margins of the pupil and the margins of the retina, leaving a small space between these two points of attachment called the **posterior chamber.**

DRAWING 22. Make a diagram of the cross-section of the eye.

After the eyeball is removed from the orbit note (1) the origin of the six eye muscles, (2) the **optic pedicle** for support of the eyeball which is a cartilaginous stalk, situated among the rectus muscles, and (3) the **optic nerve,** a stout white nerve in front of the rectus muscles. On the floor of the orbit is the **infraorbital nerve.**

C. *The Ear.*

The internal ear of the skate is located between the spiracle and the mid-dorsal line where there is an elevation of the chondocranium. A pair of small holes is present in the median line between these elevations. If the internal ear has been destroyed on one side during the dissection of the eye use the other side, being careful not to injure the brain.

Remove the skin from the region of these holes and trace the entrance of the **endolymphatic ducts** which pass through the fossae in the chondocranium. These ducts connect the cavity of the internal ear with the exterior.

Carefully shave off the cartilage of the elevations until the canal within the cartilage is exposed. It contains a curved, colorless tube, the **anterior vertical semicircular duct.** Keep this duct intact and continue the dissection until a **posterior vertical semicircular duct** is reached. Below this is the thin-walled **vestibule** from which the semicircular ducts spring. A third duct, the **horizontal semicircular duct,** is below these and may be exposed by further cutting away the cartilage, leaving the ducts and vestibule in place.

With the structures just exposed still in place identify the parts of the internal ear. The ducts are semicircular and each terminates in a sac, the **ampulla.** These are in communication with the large dorsal **utriculus** which is a part of the vestibule. The other ventral portion, the **sacculus,** is located in a pit in the cartilage. The ampullae are in connection with each other. Each is supplied with a sensory area, the white **crista,** bearing the nerve. A white mass of crystalline material or sand grains, the **otolith,** is present in the utriculus. The endolymphatic duct also enters the vestibule, but this entrance is difficult to locate in the skate.

The functions of the ear are those of hearing and equilibration. The canals in the cartilage are filled with **perilymph,** and the ducts and vestibule with a fluid, **endolymph.** Changes in pressure, either from sound waves or the change in the position of the head, appear to excite the sensory cells in the ampullae and vestibule. The ampullae and the vestibule control equilibration. The capacity to detect sound waves seems to be limited to the vestibule.

The above organs represent the inner ear of the higher vertebrates. The middle and outer ears are absent in the skate.

DRAWING 23. Make a drawing of the internal ear.

## II. THE NERVOUS SYSTEM.

The function of the nervous system is that of conduction, coördination and correlation of stimuli.

The nervous system may be divided into three parts: (1) the **central nervous system,** composed of the **brain** within the skull and the **spinal cord** within the neural canal of the vertebrae; (2) the **peripheral nervous system,** composed of the **cranial nerves** from the brain and the **spinal nerves** from the spinal cord; (3) the **sympathetic system** which controls and regulates the involuntary activities and the organs involved, such as the heart, digestive tract, respiratory and reproductive systems, and the smooth musculature in general. It is connected with outgrowths of the peripheral nervous system.

The brain and spinal cord are composed of **nerve-cell bodies** (gray matter) and **nerve-cell processes** (white matter). The cranial and spinal nerves are made up of processes only.

### 1. The Brain.

The central nervous system is developed from the tube formed originally by an infolding of the ectodermal medullary plate of the embryo. During the development of the brain there are at first three vesicles, which have been named the **forebrain** or **prosencephalon,** the **midbrain** or **mesencephalon,** and the **hindbrain** or **rhombencephalon.** The first and third subsequently divide into two. Each of the five divisions is further changed by evaginations, foldings and thickenings. The adult brain has, however, the five main divisions: the **telencephalon**; the **diencephalon** or **thalamencephalon**; the **midbrain** or **mesencephalon**; the **metencephalon** or **cerebellum**; and the **mylencephalon** or **medulla oblongata.**

Remove the skin from the top of the head back to a

point two inches behind the eyes. Cut away the cartilage and expose the brain. The white strands are cranial nerves, which pass through the cartilage and should not be injured.

The brain is situated in a cavity in the **chondocranium** and is covered by the **primitive meninx,** the membrane in which the blood vessels of the brain run. This membrane is connected here and there to the walls of the cranial cavity by strands of tissue. The space between is filled with fluid in life.

a. The Telencephalon. At the anterior corner of the main brain mass is the elongated **olfactory bulb.** Cut away the cartilage and expose the bulb. It gives off a very small **olfactory nerve** forward to the olfactory sacs. The bulb is connected by the stock, the **olfactory tract,** to the enlarged **olfactory lobes** which are a part of the main mass of the brain. Medial to these lobes and separated only by a slight groove are the **cerebral hemispheres.**

b. The Diencephalon or Thalamencephalon. Posterior to the hemispheres is the depressed **diencephalon.** The thin roof of this consists of the **choroid plexus,** blood vessels of the third ventricle. The diencephalon is the center for the coördination of sensations and is the chief controlling portion of the brain. The **optic nerve** passes from the orbit towards its ventral surface.

c. The Mesencephalon or Midbrain. The **mesencephalon** is posterior to the diencephalon and consists largely of the **optic lobes (corpora bigemina),** which are centers for the auditory, visual and skin sensations. The **trochlear** (fourth cranial) arises from the posterior edges of the optic lobes and runs forward to the muscles of the eye. The **oculomotor** (third cranial) passes to the orbit from the ventral side of the mesencephalon.

d. The Metencephalon or Cerebellum. Posterior to the optic lobes and overhanging them is a large **cerebellum.**

It is marked by longitudinal and transverse grooves. It is the center of motor coördination.

e. The Myelencephalon or Medulla Oblongata. Posterior to the cerebellum is the elongated **myelencephalon.** Its anterior part consists of the choroid plexus of the fourth ventricle, below which is the cavity of the fourth ventricle. There are two earlike projections (**auricles**) on the anterior end of the medulla.

The posterior end of the medulla marks the end of the brain which grades indefinitely into the spinal cord.

DRAWING 24. Draw the brain from the dorsal side.

2. THE CRANIAL NERVES.

The dissection of the cranial nerves in the skate is easier than in any other vertebrate animal.

There are ten cranial nerves. These nerves show a definite relation to the original segmentation of the head and to the gill. Throughout the evolution of the vertebrates each nerve continues to be distributed to homologous parts regardless of the animal. So close is this homology that structures of unknown history having the same innervation can be known as homologous regardless of great difference in function and position.

The cranial nerves are indicated either by number which corresponds to the order of their appearance or by name. Since the roots of some of these as the fifth, seventh, and eighth are intermingled as they leave the brain they should be located some distance from their origin as indicated in the directions.

a. The **first** or **olfactory** tract leaves the olfactory lobe extending to the nostrils and expanding into olfactory bulbs.

b. The **second** or **optic** tract or nerve is a stout, white nerve piercing the orbit and running from the retina to the

ventral side of the diencephalon. Since the retina is an outpushing of the brain wall, the connection it retains with the brain is not a nerve but a tract of the brain.

c. The **third** or the **oculomotor** arises from the floor of the mid-brain and ascends to the orbit near the trochlear nerve. It supplies four of the six muscles of the eye. There is a **ciliary ganglion** belonging to the sympathetic system which appears as a small brown mass on the oculomotor nerve.

d. The **fourth** or **trochlear** is a small nerve arising dorsally from the midbrain and emerging at the groove between the optic lobes and cerebellum. It supplies the superior oblique muscles of the eye.

e. The **fifth** or **trigeminus** is a very large nerve with four branches. It arises from the medulla oblongata. Its roots are located just behind the auricles of the medulla and are mingled with those of the seventh and eighth nerves. The three branches of the trigeminus are: the maxillary and the mandibular to the muscles of the jaw, and the superficial ophthalmic which runs over the eye to the snout closely united with a similar branch of the seventh.

f. The **sixth** or **abducens** is a slender nerve hidden beneath the fifth arising near the midventral line. It will be seen as a white ridge on the ventral surface of the external rectus muscle of the eye.

g. The **seventh** or **facial** is the nerve of the spiracular cleft. It arises in common with the trigeminus from the anterior end of the medulla and divides into three main branches. Two of these pass to the orbit. It supplies all the ampullae of the head and has numerous branches which go to the lateral line organs.

h. The **eighth** or **auditory** nerve extends from the internal ear to the brain. It enters the anterior end of the

medulla; its roots are mingled with those of the fifth and seventh nerves.

i. The **ninth** or **glossopharyngeal** nerve passes through the floor of the auditory capsule. It is attached to the medulla posterior to the auditory. It has several branches to the first functional branchial arch, to the pharynx and to a few sense organs on the mid-dorsal line of the head.

j. The **tenth** or **vagus** nerve is apparently made up of several cranial nerves. It has numerous roots and divides into six main ganglionated portions which supply the four posterior clefts and arches, and the heart and stomach.

Drawing 25. Add the cranial nerves to the drawing of the brain.

3. The Spinal Cord.

Expose about an inch of the spinal cord by shaving away the neural arches through which it runs. It is divided by deep dorsal and ventral fissures. The dorsal half of the system is sensory and is concerned with the bringing into the system of stimuli. The ventral half is concerned with the initiation and conduction of impulses, exciting activity of muscles, etc.

4. The Ventral Aspect of the Brain.

Free the brain from the chondocranium by cutting through the olfactory tracts and lifting up the anterior end of the brain. Cut through the two optic nerves and pare away the wall of the orbit on one side. Certain of the structures attached to the ventral surface of the diencephalon extend ventrally into a pit in the floor of the cranial cavity. Cut through the cranial nerves and across the spinal cord and lift out the brain intact. Study the ventral surface in light of the previous study of the brain. Note the distribution of the internal carotid artery.

Several additional structures are present on the dien-

cephalon. The **optic chiasma** is formed by the crossing of the optic nerves. Posterior to the optic chiasma the floor of the diencephalon bulges ventrally and posteriorly forming the **infundibulum** made up of two **inferior lobes.** From between the two inferior lobes a sac, the **hypophysis** or **pituitary body** projects caudad. It is a gland of internal secretion in mammals. Parts not identifiable on the brain will often be found adhering to the floor of the brain case.

5. The Ventricles of the Brain.

The brain retains the hollow spaces of its early tube construction as the **ventricles** or cavities of the brain.

The **fourth ventricle** is the most posterior of these. It is the cavity within the medulla oblongata. Its ventral portion is the **fossa rhomboidea.** Make a ventral sagittal cut through the brain and examine under water.

The **aqueduct** of the brain extends anteriorly from the fourth ventricle. It communicates with the cavity, the **cerebellar ventricle** of the cerebellum and the **optic ventricles** of the optic lobes. The **third ventricle** is in the diencephalon, the roof of which consists of the vascular **choroid plexus** which folds into the cavity.

Just in front of the optic lobe is a small thickened portion of the diencephalon, the **habenula,** from which a slender process, the **pineal body,** extends dorsally. The third ventricle connects by the **ventricle-of-Monroe** or **interventricular foramen** with the very small **lateral ventricles** which represent the first and second ventricles.

# CHAPTER VIII

## THE MUSCULAR AND SKELETAL SYSTEMS

### 1. The Muscular and Skeletal Structures of the Tail.

Cut a cross-section through the tail just anterior to the cut made for the injection of the arteries. Shave away a section until the end of a vertebra is reached at which point four rays, white areas of calcification which form a cross, will be seen. Examine, using a hand lens.

The outer layer is the integument bearing the placoid scales. Next is a series of voluntary muscles made up of **myotomes** or **muscle segments** which appear as whorls in the section. The layers are separated from each other by **myosepta** or **myocommae** composed of connective tissue. The myotomes are separated by an **horizontal skeletogenous septum** into a dorsal portion, the **epaxial muscles,** and a ventral portion, the **hypaxial muscles.** The muscles will not be further studied in the skate; in general they show segmentation.

The **vertebra** shows these structures: a concave **centrum** with a dorsal **neural arch** forming the **neural canal** for the spinal cord and a ventral **haemal arch** for the **caudal artery.** The arch ends in a **haemal spine** corresponding to the **neural spine** of the neural arch. Continuous with each is a **skeletogenous septum** running to the median dorsal and ventral lines.

Drawing 26. **Draw the cross-section of the tail.**

From the cross-section made above run a median sagittal section for a short distance. A vertebra is of the shape of an hourglass; diamond-shaped spaces are therefore found between the vertebrae. These contain the gelatinous **notochord** which is thus mostly restricted to the ends of each vertebra.

DRAWING 27. Draw a vertebra in sagittal section.

Cut a section of the vertebral column from the middle part of the body. Clean one side down to the cartilage. Haemal arches are not present in the body section, but they are represented by a pair of small cartilages, **transverse processes,** on the sides of the ventral part of the centrum. Within the portion of the transverse cartilaginous septum a cartilage, the **rib,** will be found. Notice that between each neural arch there is an **intercalary arch.** Find the exit of the **spinal nerves.**

DRAWING 28. Draw the cross-section of a body vertebra and a side view showing the intercalary arch.

## 2. THE SKELETON.

The skeleton of the skate is mostly cartilaginous except for a few ossifications in the vertebrae, teeth, scales, and elsewhere. Ossification is a replacement process, not a calcification or stiffening of the cartilage.

In the study of the skeleton use the demonstration skeleton, the figure, and your specimen.

### A. *The Girdles.*

The **pelvic girdle** is the **ischiopubic bar** of cartilage across the ventral side of the trunk between the pelvic fins. **Iliac processes** project from its main body dorsally, **prepubic processes** anteriorly. This girdle bears two articulating **facets.** The posterior facet bears the **metaptery-**

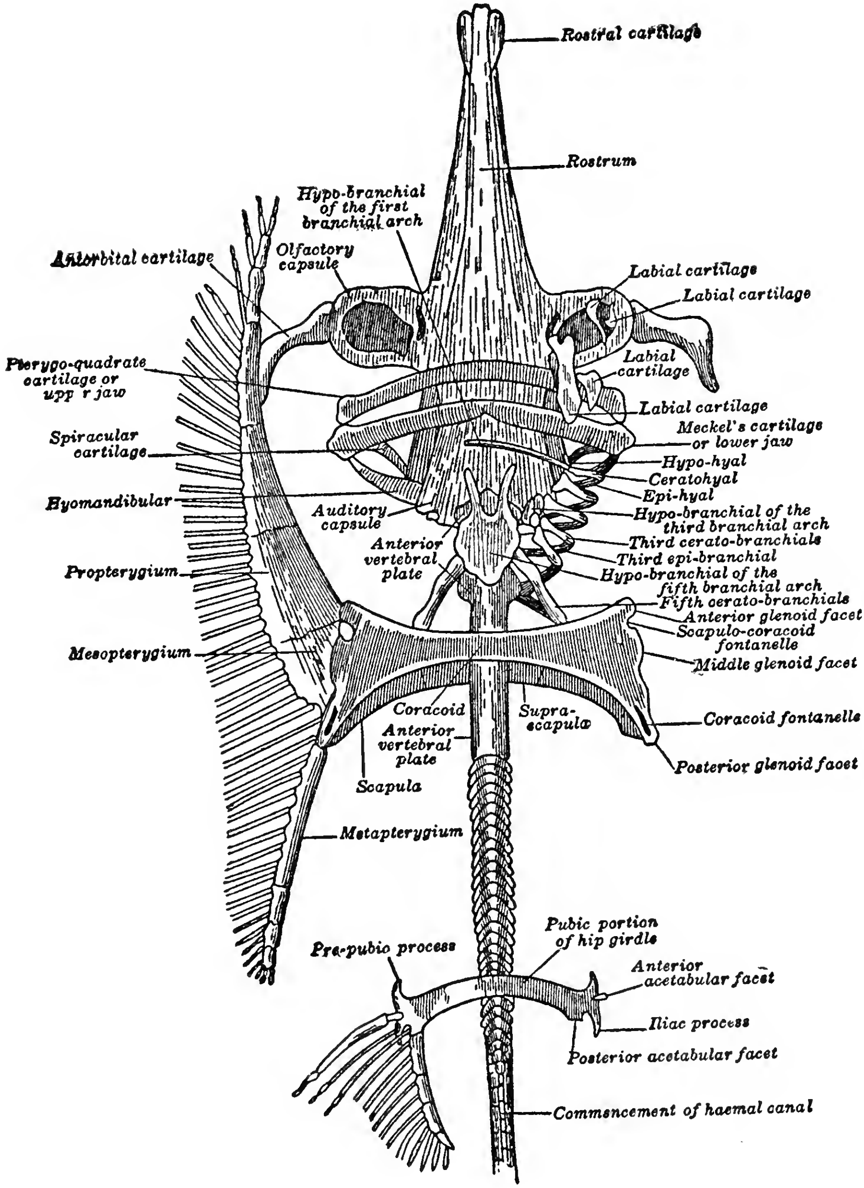


FIG. 2. The ventral aspect of the skeleton of *Raja nasuta*. (Redrawn from Parker, *Zootomy*, Macmillan and Co.)

**gium**, the strong basal piece of the hind limb. From the metapterygium and the anterior facet the jointed radials

proceed from the support of the fin. The claspers of the males are closely connected with the posterior part of the hind-fin and have a complex cartilaginous skeleton.

The **pectoral girdle** forms an almost complete hoop of cartilage which is attached dorsally to the vertebral plate. The ventral region is the **coracoid bar** and is separated from the **dorsal** or **scapular processes** by three facets to which the three pieces of the pectoral fin are attached. The anterior piece is the **propterygium**; the very small median piece, the **mesopterygium**; and the posterior piece, the **metapterygium**. All of these and a part of the girdle bear jointed radials, parts of the endoskeleton.

B. *The Skull and Visceral Skeleton.*

The **chondocranium** is the cartilaginous case inclosing the brain. At the anterior end is the **rostrum** and the **orbit** which hold the eye in at one side. On the dorsal surface are two large **anterior fontanelles** and on either side of the rostrum is an **olfactory capsule.** The chondocranium also has a **foramen magnum** for the entrance of the spinal cord, **auditory capsules** inclosing the ears, **olfactory capsules, nasal capsules,** and two **occipital condyles,** articulating with the first vertebra.

The **splanchnocranium** or **visceral skeleton** supports the gills. It consists of several **gill-arches.** Two are much modified in connection with the jaws. The first gill-arch, the **mandibular arch** of the upper jaw, is a strong transverse bar formed by the union of two **pterygoquadrate cartilages.** The lower jaw is formed by the union of two **Meckel's cartilages.** The **second** or **hyoid** is a slender arch with a ventral median **basihyal,** a **ceratohyal** on each side of the basihyal, and dorsal to these the **hyomandibular.** This articulates with the otic region of the skull and acts as a suspensor of the lower jaw.

Following these modified arches there are five **branchial arches** each typically of five pieces which form the framework of the gill region.

There are other cartilages, such as the **labial cartilages** about the nasal capsule, the **antorbital,** uniting the nasal capsule with the end of the pectoral fin and a cartilage supporting the rudimentary gill of the spiracle.

# INDEX